

## A MOUNTAIN-SCALE THERMAL-HYDROLOGICAL MODEL FOR EVALUATING REPOSITORY THERMAL EFFECTS ON MULTIPHASE FLOW IN THE YUCCA MOUNTAIN UNSATURATED ZONE

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### RESEARCH OBJECTIVES

The primary objective of this study is to develop a multidimensional, mountain-scale, thermal-hydrological (TH) numerical model for investigating the impact of decay heat from radioactive waste on unsaturated flow behavior at the proposed repository in Yucca Mountain, Nevada. This mountain-scale TH model includes heat-driven processes occurring both near and far away from the emplacement drifts. The model simulations predict thermally perturbed liquid saturation, gas- and liquid-phase fluxes, and water and rock temperature elevations, as well as the changes in water flux driven by evaporation/condensation processes and drainage between drifts—to assess the repository performance under thermal loading and future climates.

### APPROACH

The mountain-scale TH model, which consists of both two-dimensional (2-D) and three-dimensional (3-D) representations of the UZ repository system, is based on the current repository design, drift layout, geometry, thermal loading scenarios, and estimated current and projected future climate conditions. Specifically, the TH model implements the current hydrogeological conceptual model and incorporates the current, best-estimated input parameters into modeling studies of two-phase flow and heat transfer using the TOUGH2 code. Fracture-matrix interaction is conceptualized by a rigorous dual-permeability modeling approach. The 3-D representation explicitly includes every waste emplacement drift of the repository, as designed. Current and future climatic conditions are represented using a time-dependent net infiltration map with a three-step increase, in which the present-day climate lasts up to 600 years, the monsoon climate then covers the period from 600–2,000 years, and the glacial transition climate follows thereafter. The model simulations predict the TH evolution of the UZ system under repository thermal load and provide insight into moisture conditions and percolation fluxes in the UZ.

### ACCOMPLISHMENTS

The multidimensional, mountain-scale, thermal-hydrologic (TH) numerical model for the repository at Yucca Mountain has been recently calibrated against borehole temperature data at ambient geothermal conditions. The TH processes represented in the model have also been verified against field test data

on a drift scale. This mountain-scale TH model has been used to simulate the repository response of two-phase flow and heat transfer under two thermal loading scenarios, with or without ventilation operations, within the first 50 years after waste emplacement. In particular, the TH model has been used to provide predictions of repository heating effects on far-field UZ flow and TH conditions for hundreds and thousands of years after waste emplacement,

### SIGNIFICANCE OF FINDINGS

Since laboratory studies and field heater experiments, however necessary, cannot adequately recreate or represent the space and time scales relevant for a geological repository, numerical modeling plays a crucial role in providing an understanding of nuclear-waste-repository performance. The mountain-scale TH model has provided large-scale quantitative predictions and scientific understanding of TH processes in the UZ of Yucca Mountain under the designed schedule of repository thermal load and ventilation operations. In particular, model simulations have shown the ability to predict thermally perturbed liquid saturation, gas- and liquid-phase fluxes, and water and rock temperature elevations, as well as changes in water flux driven by evaporation/condensation processes and drainage between drifts. In this way, the developed model is crucial for assessing repository performance under thermal loading and future climate conditions.

### RELATED PUBLICATION

Wu, Y.S., S. Mukhopadhyay, K. Zhang, E.T. Sonnenthal, G. Zhang, and J. Rutqvist, Mountain-scale coupled processes (TH/THC/THM) models. MDL-NBS-HS-000007 REV03, Lawrence Berkeley National Laboratory, Berkeley, California, Bechtel SAIC Company, Las Vegas, NV, 2005.

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